Significant Figures

Calculating the final result for an experiment usually involves adding, subtracting, multiplying, or dividing the results of various types of measurements. Thus, it is important to be able to know what should be retained in the result of a given calculation. In other words, how many of the digits in the result are significant (meaningful)?

Rules for Counting Significant Figures

1. Nonzero integers. Nonzero integers always count as significant figures.

2. Zeros. There are three classes of zeros:
   a. Leading zeros are zeros that precede all the nonzero digits. They do not count as significant figures. In the number 0.0025 the three zeros simply indicate the position of the decimal point. This number has only two significant figures.
   b. Captive zeros are zeros between nonzero digits. They always count as significant figures. The number 1.008 has four significant figures.
   c. Trailing zeros are zeros at the right end of the number. They are significant only if the number contains a decimal point. The number 100 has only one significant figure, whereas the number 1.00×10^2 has three significant figures. The number one hundred written as 100. (notice the decimal point at the end of the number) also has three significant figures.

3. Exact numbers. Many times calculations involve numbers that were not obtained by using measuring devices but were determined by counting, for example: 10 experiments, 3 apples, 8 molecules. Such numbers are called exact numbers. They can be assumed to have an infinite number of significant figures. Other examples of exact numbers are the 2 in $2\pi r$ (the circumference of a circle), and the 4 and 3 in $(4/3)\pi r^3$ (the volume of a sphere). Exact numbers can also arise from definitions. For example, 1 inch is defined exactly as 2.54 centimeters. Thus, in the statement 1 in = 2.54 cm, neither the 2.54 nor the 1 limits

the number of significant figures when used in a calculation.

The following rules apply for determining the number of significant figures in the result of a calculation.

Rules for Significant Figures in Mathematical Operations

1. For <u>multiplication or division</u> the number of significant figures in the result is the same as the number in the least precise measurement (number with less significant figures) used in the calculation. For example, consider this calculation:

$$4.56 \times \underset{\substack{\uparrow \\ \textit{Limiting Term} \\ \textit{Only Two} \\ \textit{Significant} \\ \textit{Figures}}}{1.4} = 6.38 \xrightarrow{\textit{corrected}} \underset{\substack{\uparrow \\ \textit{Two} \\ \textit{Significant} \\ \textit{Figures}}}{6.4}$$

   The correct product has only two significant figures, since 1.4 has two significant figures.

2. For <u>addition or subtraction,</u> the result has the same number of decimal places as the least precise measurement used in the calculation. For example, consider the following sum:

$$12.11 + \underset{\substack{\uparrow \\ \textit{Limiting Term} \\ \textit{Only One} \\ \textit{Decimal} \\ \textit{Place}}}{18.0} + 1.013 = 31.123 \xrightarrow{\textit{corrected}} \underset{\substack{\uparrow \\ \textit{One Decimal} \\ \textit{Place}}}{31.1}$$

The correct result is 31.1, since 18.0 has only one decimal place.

Note that for multiplication and division significant figures are counted. For addition and subtraction the decimal places are counted.

3. For logarithms, the result's only significant numbers are those to the right of the decimal point. So, the result will have as many decimal places as the number of significant figures of the measurement.

$$\log 1.0x10^{-3} = 3.00$$

$$\underset{\text{2 Significant Figures}}{\uparrow} \qquad \underset{\text{2 Decimal Places}}{\uparrow}$$

For antilogarithms, the reverse rule is used.

$$10^{-3.000} = 1.00x10^{-3}$$

$$\underset{\text{3 Decimal Places}}{\uparrow} \qquad \underset{\text{3 Significant Figures}}{\uparrow}$$

In most calculations you will need to round off numbers to obtain the correct number of significant figures. The following rules should be applied for rounding.

Rules for Rounding

1. In a series of calculations, carry extra digits through to the final result, ***then*** round off. If you round between steps, the final result may be different from the actual result.

2. If the digit to be removed,
   a. is less than 5, the preceding digit stays the same. For example, if you want to round off 1.33 (to two significant figures), it rounds to 1.3.
   b. is equal to or greater than 5, the preceding digit is increased by 1. For example, if you want to round off 1.36 (to two significant figures), it rounds to 1.4.

When rounding, use only the first number to the right of the last significant figure. Do not round off sequentially. For example, the number 4.348 when rounded to two significant figures is 4.3, not 4.4.

Scientific Notation

1. Numbers in chemistry are often very large or very small and are conveniently expressed in the form: $\mathbf{N \times 10^{n}}$, where ***N*** is a number between 1 and 10 and ***n*** is the exponent.

2. A positive exponent tells us how many times we have to multiply the number by 10 to give the long form of the number. You can also think about it as the number of

places the decimal point must be moved to the left to obtain a number that is greater than 1and less than 10.

$$2.8 \text{ x } 10^5 = 2.8 \text{ x } 10 \text{ x } 10 \text{ x } 10 \text{ x } 10 \text{ x } 10 \text{ (five tens)} = 280{,}000$$

3. A negative exponent tells us how many times we must divide a number by 10 to give the long form of the number. You can also think about it as the number of places the decimal point must be moved to the right to obtain a number that is greater than 1and less than 10.

$$3.5 \text{ x } 10^{-4} = \frac{3.5}{10 \times 10 \times 10 \times 10} = 0.00035$$

*Information obtained (with some modifications) from:

Zumdahl, Steven S. "Appendix One: Mathematical Procedures" Chemical Principles. Ed. Richard Stratton. Houghton Mifflin, 2005. A13-A15.